RELATIONSHIPS OF RELIABILITY, AVAILABILITY & MAINTAINABILITY (RAM) TO OPERATIONAL READINESS & SUPPORTABILITY

Bernard Price

Certified Professional Logistician

Operational Availability

- **The Probability that the Equipment is Operating or in a Committable Condition to Operate at any Random Point in Time**
- **Quantitative Expression of User Need Prior to Fielding**

Operational Readiness

- **The Experienced Probability that Reported Weapon Systems are considered Up to Accomplish their Mission**

- **Unit Commanders are Responsible for Readiness Rates of their Systems After Fielding**

Operational Availability & Readiness Rate Similarity

$$Ao = \frac{\text{UP TIME}}{\text{UP TIME + DOWN TIME}} = \frac{\text{UP TIME / SYSTEM FAILURE}}{\text{(UP TIME + DOWN TIME) / SYSTEM FAILURE}}$$

$$\text{Readiness Rate} = \frac{\text{UP TIME}}{\text{UP TIME + DOWN TIME}}$$

$$= \frac{\text{NO. OF DAYS SYSTEM UP}}{\text{(NO. OF DAYS SYSTEM UP + NO. OF DAYS SYSTEM DOWN)}}$$

Derivation of Operational Availability

$$A_o = \frac{\text{UP TIME}}{\text{UP TIME + DOWN TIME}} = \frac{\text{UP TIME / SYSTEM FAILURE}}{\text{(UP TIME + DOWN TIME) / SYSTEM FAILURE}}$$

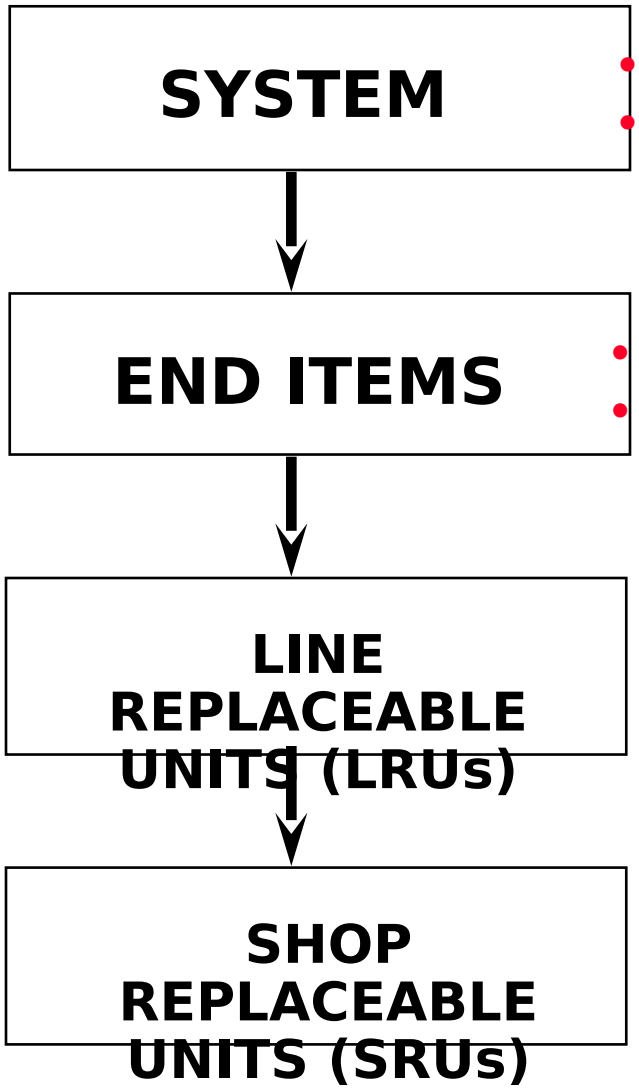
UP TIME / SYSTEM FAILURE = $MCTBF_{SYSTEM}$

DOWN TIME / SYSTEM FAILURE = Mean System Restoral Time per System Failure

$$MSRT_{SYSTEM} = MTTR_{SYSTEM} + ALDT_{SYSTEM}$$

Equipment Levels of Indenture

Other Terminology



- TOTAL WEAPON SYSTEM WITH ITS GFE
- READINESS REPORTED EQUIPMENT

- PRIMARY ITEMS BEING DEVELOPED/ACQUIRED
- SYSTEM WITHOUT GFE OR GFE ITEMS

- SECONDARY ITEMS REPLACED FORWARD
- ITEMS IMPACTING MAINTAINABILITY

- SECONDARY ITEMS USED TO REPAIR LRU OR HIGHER LEVEL SRU

Serially Configured Ao

$$Ao_{SYSTEM} = Ao_1 \times Ao_2 \times \cdots \times Ao_N$$

$$Ao_1 = \frac{Ao_{SYSTEM}}{Ao_2 \times \cdots \times Ao_N}$$

Serially Configured Reliability

$$\frac{1}{MCTBF_{SYSTEM}} = \frac{1}{MCTBF_1} + \frac{1}{MCTBF_2} + \cdots + \frac{1}{MCTBF_N}$$

Mean System Restoral Time Breakdown in Models

$$MSRT_{SYSTEM} = MTR_{SYSTEM} + CWT_{SYSTEM}$$

MTR - Mean Time to Restore with 100% Stock Availability Forward

CWT- Mean Customer Wait Time at Forward Level per System Failure

$$MTR_{SYSTEM} = MTTR_{SYSTEM} + MRDT_{SYSTEM}$$

Restoral Delay Time Contributors

- **Spares are Not Collocated with Equipment**
  - **Spares are Delivered Forward to Restore**
  - **Contact Maintenance Team Restores Equipment**
  - **Equipment is Evacuated to Restore**
- **Some ILS Elements May Not Be Satisfactory**
  - **Personnel Lacking Appropriate Skills**
  - **Personnel Not Available**
  - **Non-Functioning TMDE Forward**
  - **Forward Repair Documentation Insufficient**

Operational Availability Restated

$$Ao_{SYSTEM} = \frac{MCTBF_{SYSTEM}}{MCTBF_{SYSTEM} + MTTR_{SYSTEM} + ALDT_{SYSTEM}}$$

$$Ao_{SYSTEM} = \frac{MCTBF_{SYSTEM}}{MCTBF_{SYSTEM} + MTR_{SYSTEM} + CWT_{SYSTEM}}$$

Relationship of Customer Wait Time to LRU Logistics Response Time

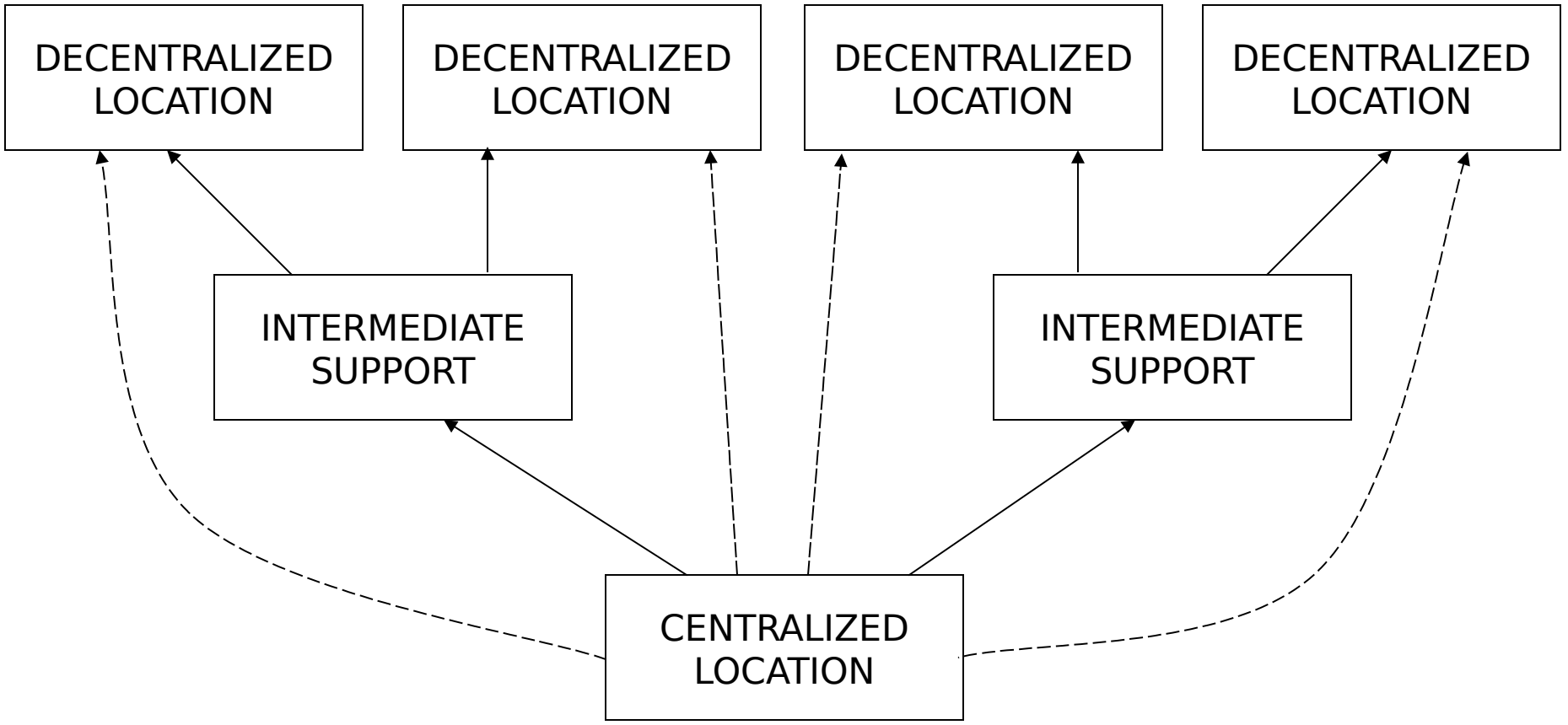
$$CWT = FILL_1 \times 0 + (1 - FILL_1) \times MTTO_1$$

$$CWT = (1 - FILL_1) \times MTTO_1$$

$FILL_1$ - Probability of Filling an Order from Forward Level Stock

$MTTO_1$ - Mean Time to Obtain a LRU at Forward Level Support

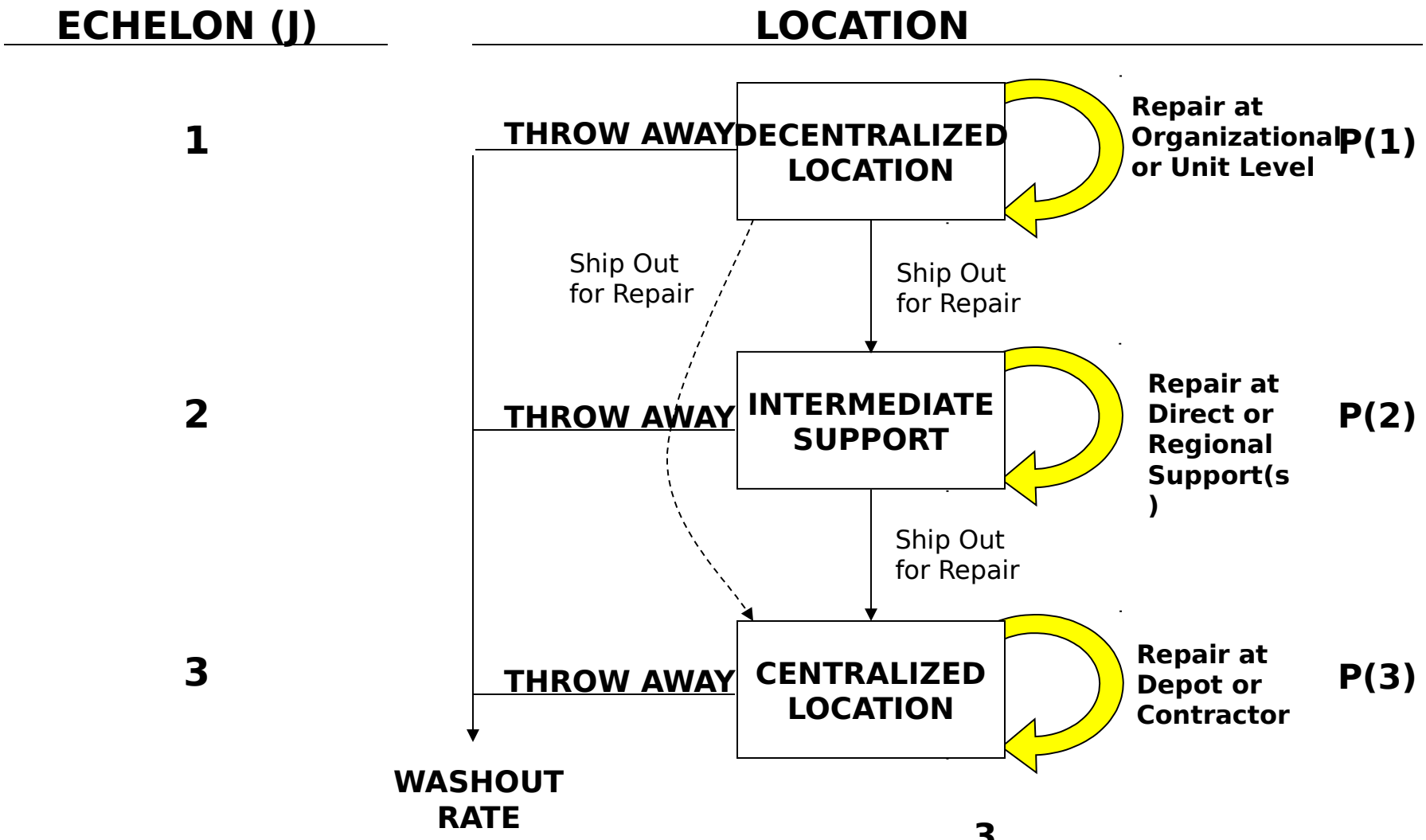
Traditional Supply Flow



Inventory Distribution

STOCKAGE LOCATION	COMMERCIAL	GOVERNMENT
CENTRALIZED LOCATION	MANUFACTURER OR PLANT WAREHOUSE	DEPOT SUPPORT OR WHOLESALE LEVEL
INTERMEDIATE SUPPORTS	DISTRIBUTION CENTER OR REGIONAL WAREHOUSE	GENERAL SUPPORT DIRECT SUPPORT (AUTH STOCKAGE LIST)
DECENTRALIZED LOCATION	RETAIL STORE	ORGANIZATIONAL SUPPORT OR SITE (PRESCRIBED LOAD LIST)

Maintenance Flow



NOTE: P(J) is percentage of repairs made at echelon J

$$\sum_{J=1}^{3} P(J) +$$

Washout Rate = 1

Determining Mean Time To Obtain Spares Values

- $MTTO_1 = RCT_1 \times PCTREP_1 + (1-PCTREP_1) \times (OST_{2 \rightarrow 1} + (1-FILL_2) \times MTTO_2)$

- FOR LRU THROWAWAY OR REPAIR AT CENTRALIZED LOCATION

$$MTTO_2 = OST_{3 \rightarrow 2} + (1- FILL_3) \times MTTO_3$$

- FOR LRU REPAIR AT THE INTERMEDIATE LOCATION

$$MTTO_2 = RCT_2 \times PCTREP_2 + (1-PCTREP_2) \times (OST_{3 \rightarrow 2} + (1-FILL_3) \times MTTO$$

OST - ORDER & SHIP TIME

FILL - ORDER FILL RATE (STOCK AVAILABILITY)

PCTREP - PERCENTAGE OF LRUs REPAIRED

RCT - REPAIR CYCLE TIME

Ao Adjustment Possibility

eriodic Maintenance Actions that may cause Down Tim
Preventive Maintenance
Tear Down and Set up
Software Change Actions
Servicing Prior to and/or After Missions

$$Ao_{ADJUSTMENT} = \frac{MCTBMA - \text{Maintenance Action Time}}{MCTBMA}$$

$$\text{Adjusted } Ao_{SYSTEM} = Ao_{SYSTEM} \; / \; Ao_{ADJUSTMENT}$$

MCTBMA - Mean Calendar Time Between Maintenance Actio

Primary Impacters of Operation Availability

- **Critical Items Within Serial Configurations**
- **Critical Items that are Line Replaceable Units**
- **Demand Frequency of Critical Items (Reliability and False Pull Rate)**
- **Mean Time to Restore (Maintainability & Restoral Delay Time Forward with 100% Stock Availability)**
- **Stock Availability at Most Forward Retail Supply Level**
- **Order and Ship Time to Most Forward Retail Supply Level**

Conditional Primary Impacters of Operational Availability

- **Additional Mean Time to Restore (when forward level supply is not co-located with the system)**
- **Frequency of Scheduled/Periodic Actions to System or Serially Configured End Items (when servicing, preventive maintenance, etc. applies)**
- **Time to Perform Scheduled/Periodic Actions**
- **End Item Redundancy or Float Stock Availability (when failed end items are sent back for repair or thrown away)**
- **Number of Serially Configured Common End Items or LRUs in System**

Secondary Impacters of Operational Availability

- **Stock Availability of Critical Item LRUs at Intermediate Retail Supply Levels**
- **Order and Ship Time to Intermediate Retail Supply Levels**
- **Centralized Support Level Mean Time to Obtain Backorders of Critical Item LRUs**

Conditional Secondary Impacters of Operational Availability

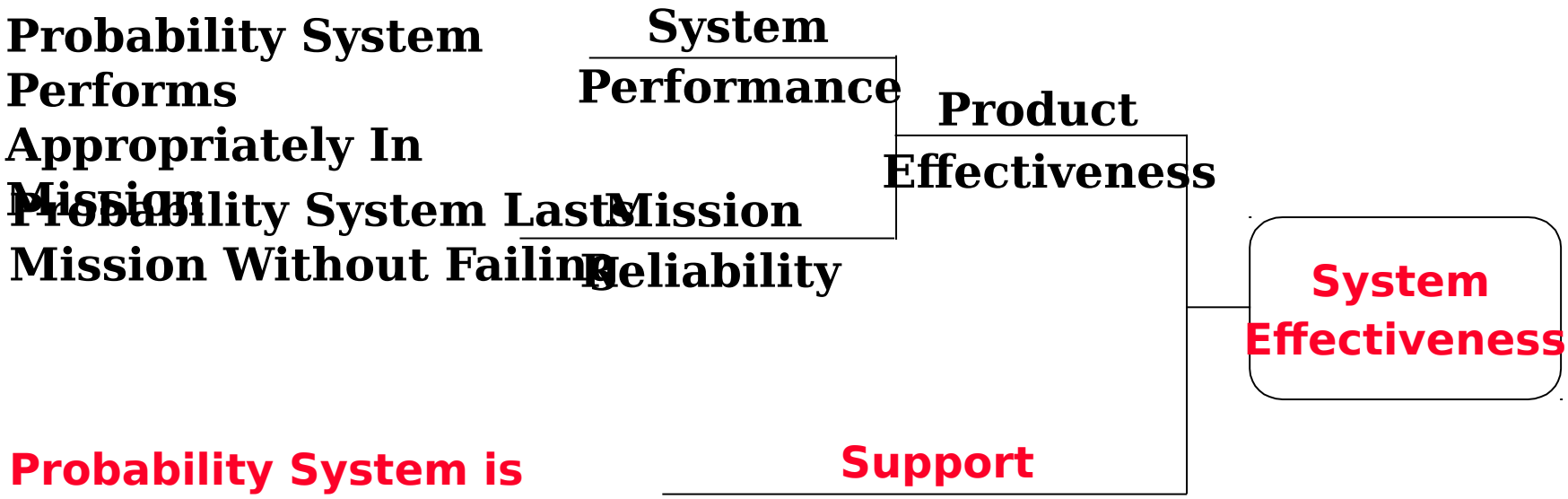
- **IF LRU IS NOT STOCKED OR REPAIRED AT INTERMEDIATE SUPPORT:**
  - **Stock Availability of Critical Item LRUs at Centralized Supply Level**
  - **Turn Around Time to Diagnose False Pulls if Performed**

- **IF LRU IS REPAIRED AT INTERMEDIATE SUPPORT OR CONTRACTOR REPAIR & RETURN APPLIES INSTEAD OF USING DEPOT LEVEL SUPPLY:**
  - **Percentage Repaired at Intermediate Repair Level(s)/Contractor**
  - **Retrograde Shipping Time to Intermediate Repair Level(s)/Contractor**
  - **Turn Around Time for Intermediate Repair Level(s) Repairs/Contractor**
  - **Stock Availability of Critical Item Shop Replaceable Units (SRUs) at Intermediate Retail Supply Level(s)**

Tertiary Impacters of Operational Availability

- **Critical LRUs Within Redundant Configurations**
- **Stock Availability of Critical Items at Centralized Supply Level**
- **Administrative & Production Lead Times of Replacements (washouts, losses or non-returns)**
- **Percentage of Critical Item LRUs Repaired at Depot or Contractor Repair Facility**
- **Depot Level Repair Cycle Time**
- **Back Order Duration Time of Critical Item SRUs**

System Effectiveness



Basically Contractor Responsibility

Typically Government and Contractor Responsibility

Relationship of RMS & Availability to System Effectiveness